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भारतीय मानक

# पर्यावरण अवस्थाओं का वर्गीकरण

## भाग 2 प्रकृति में दिखाई देने वाली पर्यावरण अवस्थायें

### अनुभाग 2 पातन और हवा

*Indian Standard*

# CLASSIFICATION OF ENVIRONMENTAL CONDITIONS

## PART 2 ENVIRONMENTAL CONDITIONS APPEARING IN NATURE

### Section 2 Precipitation and Wind

UDC 621·38·038 : 6 0·193·12

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NEW DELHI 110002

*May* 1993 **Price Group 5**

Environmental Testing Procedures Sectional Committee, LT 02

## NATIONAL FOREWORD

This Indian Standard, which is identical with IEC Pub 721-2-2 ( 1988 ) 'Classification of environmental conditions — Part 2 : Environmental conditions appearing in nature. Precipitation and wind', issued by the International Electrotechnical Commission, was adopted by the Bureau of Indian Standards on the recommendation of the Environmental Testing Procedures Sectional Committee ( LT 02 ) and approval of the Electronics and Telecommunication Division Council.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

> Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.

The concerned technical committee has reviewed the provisions of IEC 721-1 ( 1981 ) and IEC 721-3 referred in this standard and has decided that they are acceptable for use in conjunction with this standard.

Part 1 of this Indian Standard deals with classification of environmental parameters and their severities. The subsequent parts are intended to deal with the following:

a) Environmental conditions appearing in nature.
b) Classification of groups of environmental parameters and their severities.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

IS 13736 ( Part 2/Sec 2 ) : 1993
IEC Pub 721-2-2 (1988)

# *Indian Standard*
# CLASSIFICATION OF ENVIRONMENTAL CONDITIONS

## PART 2 ENVIRONMENTAL CONDITIONS APPEARING IN NATURE

### Section 2 Precipitation and Wind

### 1. Scope

This part of the standard presents fundamental properties, quantities for characterization, and a classification of environmental conditions dependent on precipitation and wind relevant for electrotechnical products.

It is intended to be used as background material when selecting appropriate severities of parameters related to precipitation and wind for product applications.

When selecting severities of parameters related to precipitation and wind for product application, the values given in IEC Publication 721-1 should be applied.

### 2. Object

To define the characteristics of precipitation and wind as background for the severities to which products are liable to be exposed during transportation, storage and use.

### 3. General

The atmosphere of the earth is in permanent motion. It is locally heated, cooled and moistened. The resulting gradients in density create high and low pressure areas. The equalizing winds do not blow directly from high to low pressure areas, but are deflected by Coriolis force due to the rotation of the earth.

The continuous horizontal movement may cause slow upward motion over wide areas, or surface heating may give more localised updrafts in thermals. The air cannot maintain its water content in vaporous form if the reduction of pressure and temperature is sufficient, and precipitation may form. As an example, an air mass of 20 °C temperature is able to contain water in a quantity of 17.3 $g/m^3$ in vaporous form. If it cools down to 0 °C the maximum water content is only 4.8 $g/m^3$.

### 3.1 *Precipitation*

The specific kind of precipitation, rain, hail or snow, is a result of complicated processes in the clouds. The temperature in a cloud varies in the vertical direction. The level at which a temperature of 0 °C occurs is referred to as the freezing level. Above the freezing level, the temperature is below 0 °C, and below this level it is above 0 °C.

In a cloud above the freezing level, supercooled water droplets exist generally in the temperature range of 0 °C to −13 °C, but in exceptional cases the temperature may reach −50 °C.

Formation of raindrops or ice crystals depends on various conditions, for instance vertical air currents, temperature distribution, and the resulting course of droplets or ice crystals within the cloud.

If, on their way down, the droplets or ice crystals pass through layers where the temperature turns positive and remains positive, they will turn into drops and reach the ground as rain. They may continue growing on their way down, dependent on conditions. The velocity increases with the diameter of the drops (see Figure 1, page 8 ). At a drop size of 5 mm to 6 mm and a corresponding velocity of 9 m/s, these large drops break up into smaller drops which in turn may grow on their way further down. The result is that the drop size distribution has an upper limit of 5 mm to 6 mm.

These raindrops may pass through layers of temperature inversion in the atmosphere where the temperature again drops below zero. This causes the drops to freeze into hailstones and reach the ground in that form. Alternatively, they may remain supercooled water droplets until they hit a surface and cause icing because they freeze immediately when they hit that surface. Another possible process is that rising air streams may lift the drops to higher regions of sub-zero temperature, thus causing freezing to occur. These hailstones may grow further by rime formation on their surface. A succession of freezing and thawing processes is possible and the hailstones may reach considerable size. The largest recorded size is 140 mm (Coffeyville, Kansas, 3rd September 1970). However, hailstone diameters of this magnitude are very exceptional.

If the temperature remains below zero throughout their descent, the ice crystals remain in a solid state and reach the ground as snow. Dependent on conditions, the crystals may grow into a large number of different but regular shapes, and form snowflakes. They may attain a diameter of 1 cm, but are very light.

### 3.2 *Wind*

The global wind systems of the atmosphere are functions of the high temperatures in the equatorial zone and the low temperatures in the polar zones, in combination with the effect of the rotation of the earth. It is wind close to the ground which is relevant for products during transportation, storage and use, whereas for certain applications well above ground consideration has to be given to wind conditions at such heights. The wind in the lower part of the atmosphere is dependent on possible local heating due to solar radiation and on the shape of the ground surface including possible buildings and other obstacles.

The effect of these local conditions is the occurrence of thermal eddies and mechanical eddies due to friction and wind shear. In daytime, the flow of air near the surface of the earth is a combination of the two, but during the night primarily only mechanical eddies exist.

The impact of these eddies on surface winds gives rise to wind gusts. The frequency of these gusts is random, but corresponds generally to time intervals of the order of a few seconds.

Wind speeds may be very high in atmospheric storms, for instance hurricanes and tornadoes. At ground level gust speeds exceeding 80 m/s have been recorded in the hurricane areas of the tropics and subtropics, and speeds of 125 m/s are possible in tornadoes though the probability of these speeds is very small.

## 4. Characteristics

### 4.1 *Rain*

Rain is characterized by the following physical parameters:

- rain intensity measured in millimetres per hour (as the height accumulated on a horizontal surface without drain),
- drop size distribution,
- falling velocity distribution,
- raindrop temperature.

Other parameters such as dissolved impurities due to air pollution, sea salts, etc., will not be considered here, even though they may have important effects on products.

A survey of characteristic parameters for different types of rain is given in Table I below.

TABLE I

*Characteristics of rain (average over long periods)*[1]

| Type of rain | Rain intensity upper limit (mm/h) | Typical drop diameter (mm) | Falling velocity (m/s) |
|---|---|---|---|
| Very light rain | Trace[2] | 0.01–0.1 | < 0.25 |
| Light rain | 1.0 | 0.1–0.5 | 0.25–1 |
| Moderate rain | 4.0 | 0.5–1.0 | 1–2 |
| Intense rain | 15 | 1.0–2.0 | 2–4 |
| Heavy rain | 40 | 2.0–5.0 | 4–7 |
| Cloudburst | > 100 | > 3.0 | > 6 |

*Notes 1.* — Rain intensities given in IEC Publication 721-3 are short-term peak intensities.

*2.* — "Trace" is the meteorological term for a rain intensity less than 1 mm/h.

The raindrop temperature will normally be the same as the wet bulb temperature of an aspirated psychrometer, but deviations may occur, for instance in a rain established from ice crystals or at the beginning of a period of rainfall.

## 4.2 *Hail*

Hail is characterized by the following physical parameters of the hailstones:

- diameter,
- density,
- falling velocity,
- impact energy.

Only stones of the larger diameters are considered here because of their damaging effect, but stones of smaller diameter are by far the most frequent. The density of hailstones is approximately 900 kg/m$^3$. The falling velocity is determined by the formula:

$$v = 5.16\sqrt{d}$$

where:

$v$ is the falling velocity in metres per second

$d$ is the diameter of the hailstones in millimetres

The impact energy is then calculated from the mass (diameter, density) and the falling velocity. Table II gives the characteristics of hailstones with diameters from 20 mm upwards.

TABLE II

*Characteristics of hailstones*

| Diameter (mm) | Mass (g) | Falling velocity (m/s) | Impact energy (*J*) |
|---|---|---|---|
| 20 | 4 | 23 | 1 |
| 50 | 59 | 36 | 39 |
| 60 | 102 | 40 | 81 |
| 70 | 162 | 43 | 151 |
| 80 | 241 | 46 | 257 |
| 90 | 344 | 49 | 411 |
| 100 | 471 | 52 | 627 |

*Note.* — Values are round figures.

### 4.3 *Snow*

Snow is generated as flakes of several millimetres in diameter and of low density. If blown by strong winds, however, snow crystals are broken and abraded into small particles down to diameters of 20 μm with an average of 80 μm. The density of snow when fallen on the ground shows great variation. Newly fallen snow has a density ranging from 70 kg/m³ to 150 kg/m³ whereas the density of old snow is 200 kg/m³ to 400 kg/m³.

### 4.4 *Wind*

Wind speed is greatly influenced by details of the local landscape and height above the ground. The greater the roughness of the ground surface, the more the wind speed close to this surface is reduced; thus there may be considerable differences between wind speeds near the ground surface and those at greater heights above the ground surface. Table III below is an illustration of this effect.

TABLE III

*Height and surface influence on wind speed*

| Height above ground (m) | Relative wind speed over different surfaces in per cent of wind speed at 500 m height (%) | | |
|---|---|---|---|
| | Town centres, tall buildings | Suburban districts, forest areas | Flat land, sea |
| 500 | 100 | 100 | 100 |
| 300 | 82 | 92 | 100 |
| 100 | 53 | 68 | 86 |
| 30 | 32 | 48 | 71 |
| 10 | 21 | 36 | 60 |
| 3 | 13 | 25 | 49 |

## 5. Classification

Rain, hail, snow and wind may have various effects on products, either each of them separately, mutually combined or in combination with other environmental parameters.

Some examples of single and combined parameters are given below.

### 5.1 *Normal rain*

Rain occurs with very different intensities which vary considerably with the latitude, climate and season. Generally, the highest rates occur in tropical thunderstorms and in hurricane-type storms.

A world record rain intensity is 30 mm in 1 min. Such rainfalls are usually short, for instance rain in a thunderstorm seldom lasts over 0.5 h.

Normal rain consists of drops of different sizes and velocities. The characteristics of the drops depend mainly on the temperature and the moisture content in the atmosphere. These atmospheric features will result in partial or complete vaporization of the falling drops. In general, higher ground temperatures and higher relative humidity give greater median drop size. Consequently, tropical rain generally consists of drops larger than those of rain in, for example, a north European location (see Figure 2, page 8 ).

### 5.2 *Driving rain*

Driving rain is a combination of rain and wind. The wind adds a horizontal velocity component to the falling velocity, and may further create underpressure in an encapsulation. The rain in itself may also create such underpressure by cooling due to low rain temperature. In the tropical zone, an intensity of 130 mm/h in combination with a wind speed of 30 m/s is the maximum one hour average to be expected. One minute peak values of rain intensity may be considerably higher than the maximum 1 h average mentioned, reaching 20 mm in the tropical zone and up to 10 mm for the rest of the world.

### 5.3 *Formation of ice*

Formation of ice occurs as a combination of rain falling on a surface cooled below 0 °C (e.g. due to radiation towards a clear night sky), or by supercooled raindrops freezing at impact. Thicknesses of glaze ice up to 75 mm may occur on antenna towers and similar high structures.

#### 5.3.1 *Air hoar*

Air hoar is formed when moist air contacts a surface cooled below 0 °C and sublimes on it. Air hoar is usually formed when the wind velocity is low. It consists of needle-like crystals, and its adhesion to surface is weak.

#### 5.3.2 *Rime*

Rime is formed as a result of repeated impinging and freezing of super-cooled water droplets carried by the wind against an object. It has a very characteristic appearance of "shrimp tails" because the points where it attaches to an object are small and grow windwards. Its colour is white and it has a granular structure. In mountainous districts rime can grow on an object at the rate of 30 mm/h or 30 cm during a night. Rime can occur simultaneously with snow causing a huge covering of snow on a suitable object. Maximum layers of 150 mm near the ground, increasing linearly to 500 mm at a height of 100 m above the ground are to be expected. The density of these layers is approximately 200 kg/m$^3$.

#### 5.3.3 *Clear ice*

Clear ice is formed when supercooled raindrops freeze on a surface. It is hard and opaque or transparent. It can form a layer-like structure of opaque and transparent layers with small air bubbles inside the structure. Clear ice has no particular structure to be seen. It is compact, its density is high and its adhesion force is strong. Clear ice is formed when the temperature is low and wind velocity is high.

### 5.3.4 *Glaze ice*

Glaze ice is formed when supercooled raindrops fall on a surface and a waterfilm is formed before freezing. Its density is high as well as its adhesion, and it has no air bubbles.

### 5.3.5 *Process of ice formation*

The type of formation of ice depends on:

- air temperature,
- wind velocity,
- diameter of supercooled water droplets,
- liquid water content.

In Figures 3 and 4, page 9, the relationship between the types of formation and droplet diameter, wind velocity and temperature are presented.

The formation of ice on a cylinder-shaped surface depends on:

- the radius of the cylinder,
- wind velocity,
- water drop size.

A limited radius can be found for each velocity and droplet size above which no, or very little ice is formed (See Figure 5, page 9 ).

### 5.4 *Hail*

In most parts of the world hailstones with diameters up to 20 mm are probable, but diameters over 50 mm have a low probability of occurrence.

### 5.5 *Snow load*

The maximum snow load is generally encountered in the southern part of areas having cold winters (for the northern hemisphere, and vice versa for the southern), and particularly in parts of these areas dominated by a maritime climate. A snow load of 2 kPa corresponding to a depth of 2 m new snow or 0.7 m old snow, is to be expected in these parts. In mountainous areas it may be up to ten times greater.

### 5.6 *Drifting snow*

Drifting snow is a combination of snow and wind. Under these conditions the snow may contain very small particles able to penetrate minute slots and joints in products. The horizontal mass flux diminishes rapidly with the distance above ground. The maximum values to be expected are those given in Table IV below.

TABLE IV

*Maximum horizontal mass flux of snow*

| Height above ground (m) | Horizontal mass flux ($g/(m^2 \cdot s)$) |
|---|---|
| 10 | 310 |
| 1 | 560 |
| 0.5 | 800 |
| 0.1 | 3000 |

### 5.7 *Wind force*

The wind exerts on structures a force which is a function of average wind speed and the size and shape of the object. For a flat plate perpendicular to the wind direction, the force is given by the formula:

$$F = 0.65\, v^2 A$$

where:

$F$ is the force in newtons

$v$ is the average wind speed in metres per second

$A$ is the plate area in square metres

Wind gusts cause short force impulses which in some cases may be periodic and cause large vibration amplitudes if in resonance with the natural response frequency of the structure. The frequency of these gusts is generally below 1 Hz.

A special phenomenon is the release of a double row of whirls downstream from a cylinder perpendicular to the direction of the wind. This release reacts as a periodic force on the cylinder perpendicular to the direction of wind. The frequency of this force is given by the formula:

$$f = 0.195 \frac{v}{d}$$

where:

$f$ is the frequency in hertz

$v$ is the wind speed in metres per second

$d$ is the cylinder diameter in metres

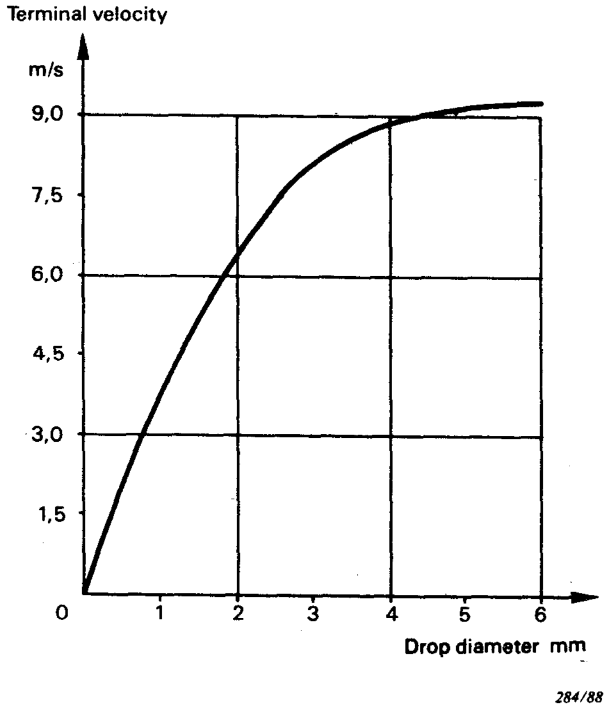

FIG. 1. — Terminal velocity of rain drops in still air at atmospheric conditions: 101.3 kPa, +20°C.

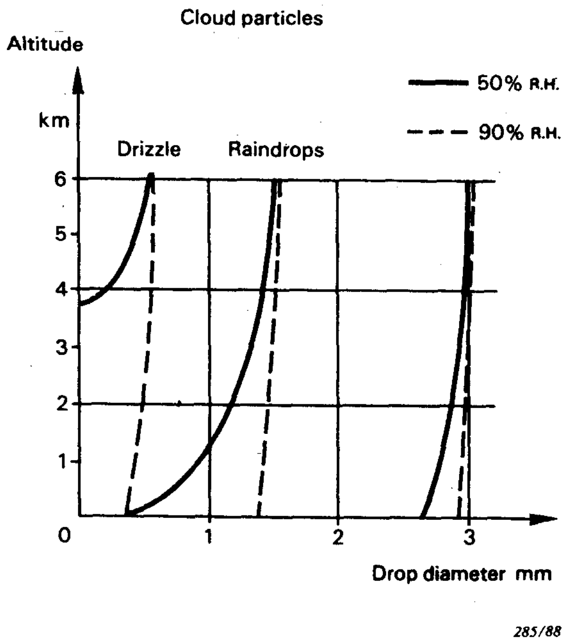

FIG. 2. — Variation in drop size with altitude due to evaporation at different values of relative humidity (R.H.).

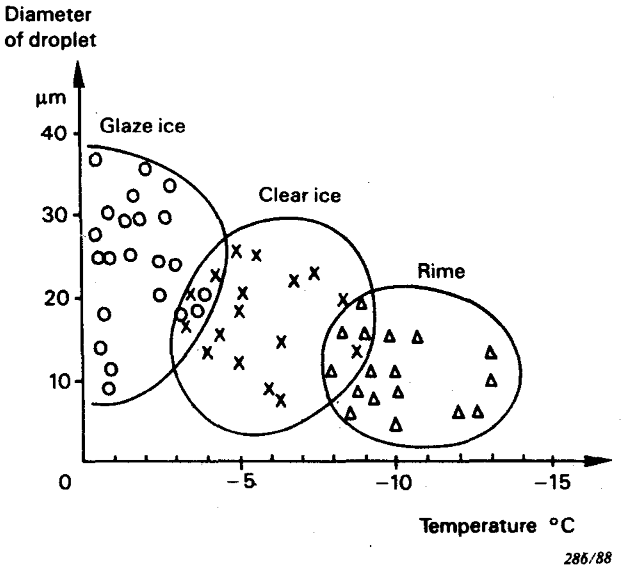

FIG. 3. — Three types of ice formation as functions of temperature and droplet diameter.

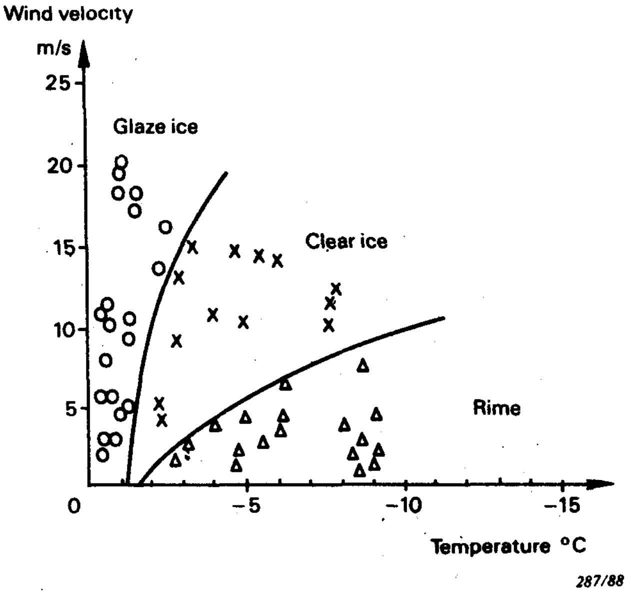

FIG. 4. — Three types of ice formation as functions of temperature and wind velocity.

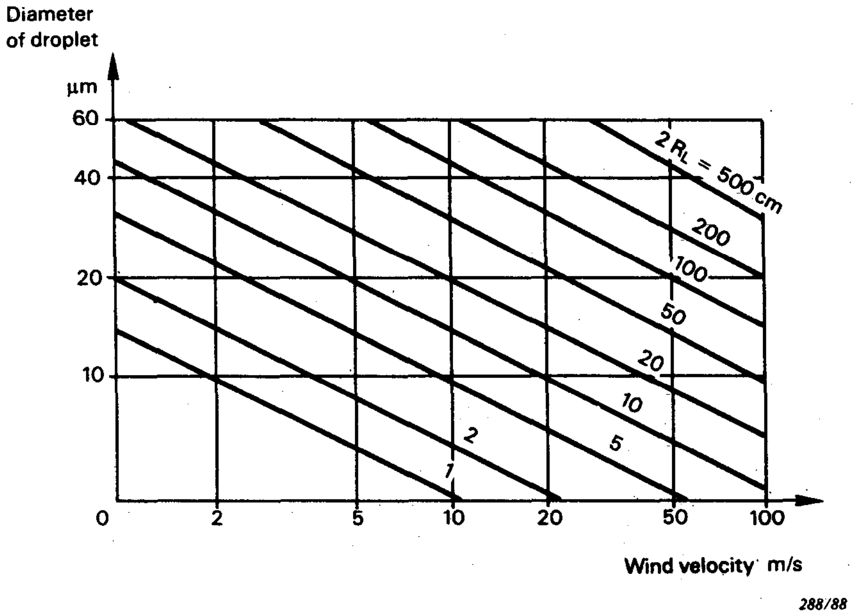

FIG. 5. — Limiting radius ($R_L$) of cylinder above which no, or very little, ice is formed.

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